An LDRD Success Story

Lawrence Livermore National Laboratory

Tiny sensors, similar to the one shown here compared with a penny, could be embedded in the nation's nuclear weapons to detect changes such as cracks or corrosion in weapon components.

Keeping the Nation Safe

As the nation's nuclear weapons stockpile decreases and its weapons age, Lawrence Livermore is developing new materials and more cost-effective technologies for maintaining the safety, security, and reliability of the remaining stockpile weapons.

Transforming the Nuclear Stockpile

Development of new nuclear weapons systems stopped nearly two decades ago. Today, the nation's stockpile is maintained through the NNSA's science-based stockpile stewardship program in the absence of testing. But, as weapon components age and the stockpile shrinks, meeting the challenge of certifying the stockpile's safety, security and reliability without testing requires ever more sophisticated scientific understanding and better technologies. Procedures developed during the Cold War to ensure that the stockpile meets all performance requirements must be transformed with a more efficient approach.

Livermore scientists and engineers, funded by LDRD, are providing technical leadership to achieve this transformation by creating new materials, processes, and sensors that will do the job of maintaining the stockpile better, faster, and cheaper.

Traditionally, a few randomly selected warheads and bombs are removed from the field every year and transported to the NNSA's Pantex Plant in Texas, where they are disassembled for close inspection, reassembled, and returned to the stockpile. At least one warhead of each type is destroyed during inspection. This process of inspecting and maintaining stockpile weapons, called surveillance, is time-consuming, costly, and cumbersome. Plus, as the nation's stockpile shrinks, ensuring the reliability of the remaining weapons becomes increasingly important. The new materials developed under LDRD funding, promise to dramatically reduce the time and surveillance costs, extend the lifetime of weapon components, and ensure that the weapons remaining in the stockpile are safer, more reliable, and more secure.

Transformational Materials

Significant Advances Through New Materials

The Transformational Materials Initiative (TMI) developed new materials to transform stockpile surveillance—sensors to detect changes in stockpile weapons, more robust and less expensive weapon materials, and reformulated high explosives to make weapons inherently safer. These results will achieve significant immediate and long-term cost savings for the nuclear weapons complex.

Immediate cost savings

- **High Explosives.** TMI achieved two major advances in understanding the chemistry and materials science of high explosives. First, the project formulated a new insensitive high explosive with less-sensitive detonation properties that will improve safety. Second, the project developed a new ionic liquid that can dissolve and re-crystallize TATB (triaminotrinitrobenzene), a powerful yet insensitive high explosive prevalent in both nuclear and conventional weapons (see text box on next page). TATB is difficult to synthesize and few producers manufacture it. This TMI advance will realize big savings by recycling TATB from disassembled weapons.
- **Metals.** TMI developed a new material that will replace one of the most expensive components in a nuclear weapon with a metal that is far cheaper but that meets or exceeds the physics and engineering requirements for ductility.

Long-term cost savings

- **Multifunctional Materials.** Polymeric organic compounds used as fillers inside nuclear weapons break down over time. TMI developed longer-lasting materials to replacing the limited-lifetime materials now in use. Plus, these new nanoscale reactive fillers have chemical properties that sense and absorb hydrogen gas, which can degrade weapon performance.
- **Embedded Sensors.** Tiny, rugged sensors developed by TMI, some of them using multifunctional materials, can be embedded in every nuclear weapon to continually monitor weapon health. These embedded sensors will provide instantaneous detection of corrosion, cracks, and composition-changing properties without having to transport and dismantle the weapon. Using embedded sensors, for the first time in the history of the complex, will yield a huge payoff in costs and manpower.

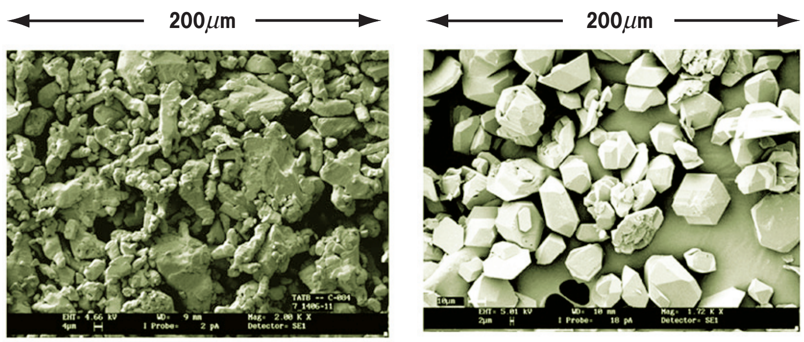
About LDRD

The Laboratory Directed Research and Development (LDRD) Program is LLNL's primary mechanism for funding cutting-edge R&D to enhance the Laboratory's scientific vitality. Established by Congress in 1991, LDRD collects funds from sponsored research and competitively awards those funds to high-risk, potentially high-payoff projects aligned with Laboratory missions.

The Transformational Materials Initiative team combines expertise in materials synthesis, characterization, theory, and modeling. Their results will ensure the continued success of the Stockpile Stewardship Program by enabling a smaller, safer, and more agile U.S. nuclear weapons complex.

Recycling High Explosives

The insensitive high explosive TATB, used in both nuclear and conventional weapons, is difficult to synthesize and hard to dissolve. Because the nuclear weapons complex and the Department of Defense use a lot of TATB, finding a way to recycle TATB by dissolving and resynthesizing it would represent a huge cost savings. Commercial TATB [Fig. (a)] has poor crystal quality, low density, and high impurity levels. After being dissolved with the ionic liquid developed by the TMI team and then recrystallized, TATB [Fig. (b)] shows improved crystal quality, higher density, and reduced impurity levels. The recrystallized TATB also has lower shock sensitivity, making it safer to handle than commercial TATB.

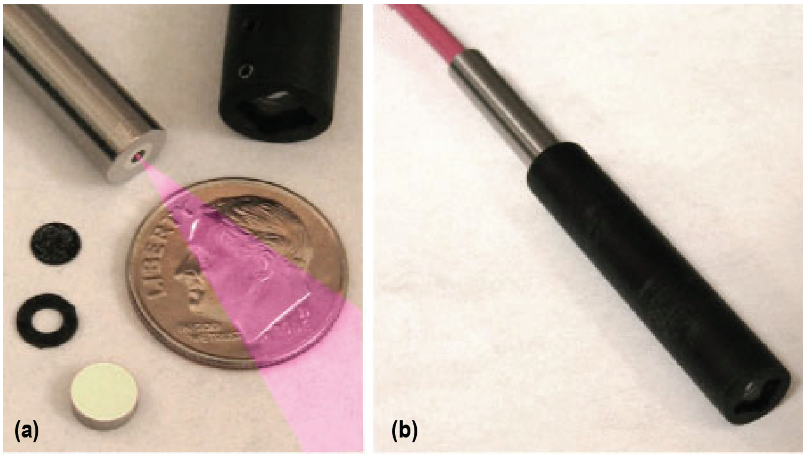


(a) (b)

Images taken with a scanning electron microscope reveal the shape of TATB crystals (a) before and (b) after recrystallization with the ionic liquid 3-ethyl-1-methylimidazolium acetate.

Monitoring a Nuclear Weapon

The ideal weapon sensor is a durable device with almost zero size and weight that can be embedded inside the warhead and read by a portable diagnostics unit. The TMI team has developed several sensors that meet these exacting criteria. Many of these embedded sensor designs use glass fibers measuring about 75 micrometers in diameter, smaller than the thickness of a human hair. One fiber-based gas sensor detects and captures hydrogen, which is both explosive and corrosive, by using photoacoustic Fourier transform infrared spectroscopy to detect changes in the physical properties of an organic getter as it captures hydrogen.



(a) The components inside the getter-based hydrogen sensor (counterclockwise from the top): the sensor case; a fiber bundle, consisting of a central laser-delivery fiber surrounded by six light-collection fibers; a getter made of DEB (1,4-bis(phenylethynyl) benzene) and silicone rubber; a spacer ring; and a mirror. (b) the assembled prototype.

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